Series 1929 Number 24

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Survey
of
Hennepin County, Minnesota

By

P. R. McMILLER, in Charge, C. C. NIKIFOROFF
E. A. FIEGER, SAM HILL, and C. H. MATTSON
University of Minnesota
and
G. A. SWENSON and W. C. BOATRIGHT
United States Department of Agriculture

Bureau of Chemistry and Soils
In cooperation with the
University of Minnesota Agricultural Experiment Station

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SOIL SURVEY

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By P. R. McMILLER, in Charge, C. C. NIKIFOROFF, E. A. FIEGER, SAM HILL, and C. H. MATTSON, University of Minnesota, and G. A. SWENSON and W. C. BOATRIGHT, United States Department of Agriculture

COUNTY SURVEYED

Hennepin County lies in the eastern part of Minnesota, its eastern border being less than 25 miles from the Wisconsin State line (fig. 1). It is irregular in shape, and the land area is 565 square miles, or 361,600 acres. Minneapolis, which lies wholly within the county, occupies an area of approximately 60 square miles. Three rivers, the Mississippi and two of its tributaries—Minnesota River and Crow River—form parts of the county boundaries. An area comprising about 14 square miles lies east of the Mississippi River. All this area, with the exception of about 2 square miles, which comprises the township of St. Anthony, is included within the city limits of Minneapolis. Ramsey County, in which is located the city of St. Paul, the State capital, adjoins Hennepin County on the east.

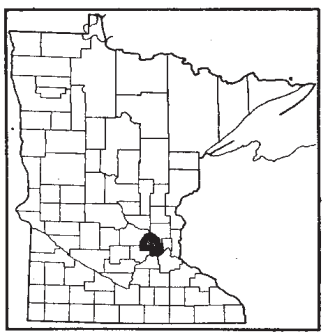

FIGURE 1.—Sketch map showing location of Hennepin County, Minn.

The land area of Hennepin County comprises three distinct physiographic divisions, all being the results of the action of the great ice sheet which covered the greater part of the State many centuries ago and of the waters which flowed from it. These divisions are designated as smooth plains, hilly belts, and undulating plains. Each is characterized by different soils and distinct topographic features. Geologically the smooth plains consist of sandy water-laid materials, the hilly belts of terminal moraines, and the undulating plains of ground moraine.

The smooth plains were formed by the deposition of sand and gravel, together with some silt, from the running waters of shallow glacial streams which covered much wider areas than any of the present rivers. Both Minnesota and Mississippi Rivers were glacial streams, much larger than at present, and they were responsible for the deposition of much assorted glacial material. Both rivers are bordered by the terraced alluvial plains which extend back for a distance ranging from 1 to 6 miles. In some places they are bordered by pronounced escarpments ranging from 25 to more than 50 feet in height.

In hilly belts, the hills have no systematic arrangement as to position, equality of elevation, or conformity of shape. They occupy the whole of Hennepin County, except that part occupied by the smooth plains mentioned and a small area in the north-central part, where the relief is less pronounced. In some places this morainic area has very pronounced topographic features, the surface being

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hilly with conspicuous knolls and hills rising sharply above the adjacent land. Throughout the morainic region, many low basins, some with and some without natural drainage outlets, are filled with water and form the numerous lakes scattered throughout the county. Lake Minnetonka, with its many arms and branches, lies in a part of this region.

The undulating plains have a smoother relief than that of the hilly belts. They occupy only a small part of the county, being confined to Corcoran, northern Medina, and eastern Greenwood Townships. Their surface relief ranges from undulating to gently rolling. Their whole area, however, is spotted with depressions where natural drainage conditions are such as to interfere with the adaptability of the land for crops.

Minnesota River is bordered by a pronounced belt of swampy land forming a continuous broad flat-bottomed valley inclosed between high abrupt walls which rise from 100 to 125 feet above the water surface.

Owing to the youth of the glacial deposits, very little of the land surface has reached the stage of advanced stream dissection. A large part of the county is poorly drained, and many shallow lakes and swamps containing stagnant water are scattered over it. They are more numerous in the morainic areas than on the more level till plains and river terraces. On the sandy outwash plains adjacent to Mississippi River, swamps and low-lying poorly drained mineral soil areas are more extensive than in the region of similar soils adjacent to Minnesota River.

The streams of Hennepin County flow in several directions, but the waters of all of them eventually reach Mississippi River, either emptying directly into it or through its numerous tributaries. Crow River, which forms a part of the northwestern boundary, receives part of the drainage from the northern part. The central part and a portion of the southern part are drained into Lake Minnetonka.

Both Mississippi and Minnesota Rivers flow in valleys ranging from 20 to 120 feet in depth, the valley of the Minnesota being the deeper. The valley of the Mississippi ranges from one eighth to one fourth mile in width, and the stream has a rapid current. From Minneapolis to Fort Snelling, a distance of about 4 miles, the river flows in a narrow deep gorge cut through limestone and sandstone rock. Minnesota River, which joins the Mississippi just below Fort Snelling, is from 300 to 400 feet wide, but in flood times it spreads over the adjacent swampy lands. Its flow is normally sluggish, except at times in the spring when it becomes more rapid owing to an increased quantity of water discharged into the river from melting snow and ice. Shingle, Elm, Rush, and Bassett Creeks drain portions of the northern and central parts of the county. Bassett Creek rises in Medicine Lake. Minnehaha Creek, the outlet of Lake Minnetonka, flows from Grays Bay, the eastern arm of the lake, in a general eastward direction through a series of swamps and small ponds and enters Mississippi River near Fort Snelling. About one half mile from its mouth, it drops over a limestone ledge into a deep narrow gorge, forming the famous Minnehaha Falls. Lakes Harriet and Calhoun, both within the City of Minneapolis, drain into Minnehaha Creek through small tributaries. Ninemile Creek drains a portion of the southern part of the county. Near the village of Bloomington it enters a deep val-

ley in which it flows for 2 miles, then empties into Minnesota River. Purgatory Creek rises south of Lake Minnetonka in spring-fed swamps. Most of its course is through low swampy ground, but for the last 3 miles before it joins Minnesota River it drops 100 feet into a gorge cut through glacial drift and limestone.

Hennepin County has within its borders a great number of lakes, the largest of which is Lake Minnetonka. This lake has rare scenic beauty, and along its shores are situated many summer cottages, resorts, and beautiful homes. With the exception of one of its arms, Smithtown Bay, which projects into Carver County, Lake Minnetonka lies wholly within the southwestern part of Hennepin County. It is an irregular expanse of water, lying on till deposits and surrounded in some places by sharp bluffs and knolls of clayey material. It extends about 23 miles from east to west and about 12 miles from north to south. Other important lakes are Independence, Bryant, Medicine, Calhoun, Harriet, Nokomis, and Cedar. All the larger lakes have natural outlets, either through swamps or small streams, and most of them have sandy bottoms and contain clear fresh water. They form desirable places for bathing, boating, fishing, and other aquatic sports.

The mean elevation of the county is about 925 feet above sea level. The elevation increases from north to south. The highest points are in the south-central and southwestern parts where the elevation is about 1,000 feet. Lake Minnetonka is 930 feet above sea level, and much of the adjacent hilly land rises to a height of 1,000 feet. The elevation of Minnesota River is about 700 feet. Above St. Anthony Falls the elevation of Mississippi River is 802 feet, and 1 mile below the falls is 720 feet, a drop of 82 feet.

Nearly all of Hennepin County, except some of the sandy plains along Minnesota and Mississippi Rivers and parts of some of the western townships, was originally covered with hardwood forests. It lies in that region known to the early settlers as the "Big Woods", a deciduous forest belt, including white oak, maple, basswood, elm, butternut, ironwood, cottonwood, and boxelder trees, widely distributed in south-central Minnesota. The sandy plains, though in most places nearly bare of trees, supported a scattered growth of scrub oak and brush. Some of the bottom lands, which were more or less subject to overflow, were heavily covered with elm, ash, cottonwood, and willow. Those parts originally grassland were confined to areas along the old terraces of Mississippi and Minnesota Rivers and to areas of heavier soil in the northwestern part of the county. In the southern part of Eden Prairie Township, an area including many square miles was always treeless, and a large area in the vicinity of Corcoran in the northwestern part of the county was also at one time prairie. Some of the peat bogs support a stand of tamarack, others, where the peat is shallow and the water table far enough below the surface, support willow, and the remainder support sedges and grasses of various kinds.

Hennepin County was organized March 6, 1852. It was named for Louis Hennepin, a Franciscan priest, who ascended Mississippi River as far as the Falls of St. Anthony in 1680. His visit seems to have been the first made by any white man to the country included in the present county. It was not until 1819 that any settlement of civilized people was made, and then only a garrison of United States

troops under command of Colonel Leavenworth who had orders to take command of the fort which was located on the site now occupied by Fort Snelling but was then known as Fort St. Anthony.

Cultivation of the land was not begun until about 1823, and then on only a very small scale by some Swiss colonists who came down Minnesota River from the north and were allowed to settle on the reservation at the fort. Here they established little farms and grew vegetables and grains for the use of the garrison. The first land brought under cultivation outside the fort was near Lake Calhoun in 1830. Here an Indian colony was established with the permission of a Government Indian agent, and a large tract of land was devoted to the production of corn and wheat. Across Mississippi River, in a small settlement which later became the town of St. Anthony, incorporated as a city in 1855, with a population of 2,000, Franklin Steele was the first settler who engaged in agriculture on a small scale. The land on the west side of the river, a part of the military reservation, was thrown open to squatters in 1854. The population in that year was estimated at 200, and the name of Minneapolis was given to the town. By 1857, the population had increased to more than 2,000, and in 1866 the town was incorporated as a city. The two cities, St. Anthony on the east side of the river and Minneapolis on the west side, were united in 1872, retaining the name of Minneapolis. From this time, actual settlement of the farm lands of the county began in real earnest and steadily increased thereafter. The period between 1860 and 1870 was marked by a large influx of settlers, the population of the county, outside of Minneapolis, being 10,300 in 1860 and 18,500 in 1870. Since that time the growth in the rural population has been substantial. The population of the county in 1930[1] was 517,785, of which 33,976 were rural. Of the rural population 16,733 were classed as rural farm, and 17,243 as rural nonfarm.

Foreign nations most largely represented in the population are Sweden, Norway, Canada, Russia, Poland, Germany, and England. Of the 3,981 farms in 1930, owners operated 3,021, managers 79, and tenants 881.

Minneapolis, the county seat of Hennepin County and the largest city in the State, is located in the east-central part of the county at the site of St. Anthony Falls on the Mississippi River. Its business district lies about 10 miles west of that of St. Paul, the capital of the State, and about 18 miles west of St. Croix River, the boundary between Minnesota and Wisconsin. In 1930 it had a population of 464,356 and in 1920, 380,582, a gain in the 10-year period of more than 22 percent. Minneapolis is an important railroad and manufacturing center, and it is the principal distributing center for the Northwest. During 1930 the freight received and forwarded at Minneapolis by the railroads was more than 566,000 carloads of merchandise and produce. Minneapolis is nationally known as a city possessing unusual natural scenic beauty. It is dotted with beautiful lakes, most of which are embraced within a comprehensive park system. It is the seat of the University of Minnesota. Adjacent to the southern city limits is Fort Snelling, a Government military post occupying about 1,500 acres and lying at the apex of the angle formed by the Minnesota and Mississippi Rivers.

[1] Soil survey reports are dated as of the year in which the field work was completed. Later census figures are given when possible.

Besides Minneapolis, there are a number of incorporated towns. The county is adequately supplied with good railroad facilities, 10 trunk-line railroads, 4 of which are transcontinental, operating into Minneapolis. Minneapolis is at the head of river navigation on the Mississippi. Regular service is maintained to and from St. Louis, Mo., during the navigation season. The city maintains a municipal airport and is served by air mail, air express, and air-transportation service. The Lake Minnetonka district and other suburban districts are served by bus. A system of well-maintained highways, many of which are paved, radiate from Minneapolis in all directions. All the villages and suburban centers are connected by hard-surfaced, graveled, or good dirt roads. Schools and churches are conveniently located and telephone service is available to all parts of the county. Local and transcontinental bus and truck lines have terminals in Minneapolis.

Many industrial manufacturing plants are located in Minneapolis and in the adjacent villages, producing nearly 900 different commodities, many of which are distributed widely throughout the Nation and in foreign countries. In Minneapolis alone, more than 40,000 persons are employed in factories. Some of the important products manufactured are flour and other grain-mill products; linseed oil, cake, and meal; cloth bags; furniture; structural and ornamental iron and steel; paints; rotary pumps; road machinery; electrical machinery, apparatus, and supplies; and manufacturing machines of various kinds.

Minneapolis is the largest flour-producing center in the world, its mills having a daily capacity of 53,150 barrels. The grain-storage capacity is more than 91,000,000 bushels.

CLIMATE

The principal features of the climate of Hennepin County are long cold winters and short warm summers. Freezing temperatures usually prevail from the middle of November through March, and in some years frosts may be expected in September and May. The lowest temperature ever recorded in the summer was 36° F., in the month of June.[2] The mean temperature of the winter is 16.1° and of the summer is 69.9°. Fluctuations of temperature are more common in the spring and autumn than they are in summer and winter. The summers are characterized by moderate temperatures, though hot spells in which the temperature rises above 90° commonly occur. Their duration, however, is short, lasting from 2 to 5 days. The highest temperature recorded for the county is 102°, in July.

The mean annual precipitation is 27.66 inches at Minneapolis. It is nearly 3 inches more at Maple Plain, in the west-central part of the county. The average annual snowfall is about 44 inches. Nearly two thirds of the total precipitation falls during the spring and summer months. Owing to relatively low evaporation, the precipitation is in general sufficient for the production of ordinary farm crops. Occasionally, however, short periods of drought, occurring usually in middle or late summer, reduce the yields. Damage from drought is more severe on the lighter soils devoted to the production of truck crops. From December to March the ground is usually

[2] The occurrence of summer frost on peat soils is discussed on p. 26.

covered with a thick blanket of snow which prevents the deep penetration of frost and offers protection to forage crops and fall-sown grains. Hailstorms and tornadoes sometimes occur, resulting in some damage to crops and buildings.

The average frost-free season, as recorded at the Weather Bureau station in Minneapolis, is 164 days, from April 27, the average date of the latest killing frost, to October 8, the average date of the earliest. The average frost-free season at Maple Plain is more than a month shorter than in the city.

The prevailing winds, which from November to April are northwesterly and from May to October southerly, are rarely of such velocity as to be destructive to crops. At times in the spring, on the very lightest-textured soils, where protection by trees or other means is lacking, some damage results from severe windstorms.

The climate varies appreciably in different parts of the county. In the vicinity of the large bodies of water, as Lake Minnetonka, and near Minneapolis, the first killing frosts usually occur somewhat later in the fall, owing to the modifying influence of the water of the lakes and the smoke-filled atmosphere of the city. Local increases in liability of crops to damage by frost are noted in different situations, as in the lower-lying depressions and on the peat and muck soils.

The climatological data in table 1, giving the normal monthly, seasonal, and annual temperature and precipitation for Hennepin County, have been compiled from the records of the United States Weather Bureau station at Minneapolis. This station is located in the heart of the city, at an elevation of 918 feet. The records cover a period of 41 years.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Minneapolis, Minn.*

[Elevation, 918 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1910)	Total amount for the wettest year (1868)	Snow, average depth
	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*	*Inches*
December	19.6	56	−27	0.98	0.31	0.55	7.3
January	12.7	52	−33	.86	1.08	1.96	10.2
February	15.9	64	−33	.95	.51	1.75	8.5
Winter	16.1	64	−33	2.79	1.90	4.26	26.0
March	29.6	83	−17	1.42	.09	9.00	9.2
April	46.4	86	9	2.23	.64	2.01	3.7
May	57.7	93	22	3.67	1.39	4.37	.3
Spring	44.6	93	−17	7.32	2.12	15.38	13.2
June	67.5	98	36	4.22	1.24	4.23	0
July	72.3	102	44	3.73	.74	3.09	0
August	69.9	100	42	3.12	1.56	2.81	0
Summer	69.9	102	36	11.07	3.54	10.13	0
September	61.4	97	29	3.13	2.58	2.82	(1)
October	48.9	86	16	2.08	.86	4.92	.5
November	32.4	73	−13	1.27	.59	4.13	4.3
Fall	47.6	97	−13	6.48	4.03	11.87	4.8
Year	44.5	102	−33	27.66	11.59	41.64	44.0

[1] Trace.

AGRICULTURE

The sandy soils of Hennepin County, lying adjacent to Minnesota and Mississippi Rivers, have been under cultivation for about 75 years. Because of the ease with which they could be cleared and tilled, these were the first lands to be brought under the plow. Development was naturally slower in the more thickly wooded areas, because of the dense growth of hardwoods and the difficulty of clearing. From the time of the earliest settlement, general farming, including the production of small grains, corn, potatoes, and tame hay, together with the raising of hogs and dairy cattle, has been practiced.

In 1879, according to the Federal census, the principal cereal crops, named in order of their importance, were wheat, corn, oats, rye, and barley. In 1929, the order was corn, oats, barley, wheat, and rye.

The outstanding feature in connection with the production of the cereal crops is the steady decline in the acreage devoted to wheat. The Federal census of 1930 reports only 5,802 acres in wheat in 1929, but in 1919, this crop was grown on 29,819 acres; 20 years before that, on 36,117 acres; and in 1879, on 49,020 acres. At present both spring and winter wheat are grown, a slightly smaller acreage being devoted to spring wheat than to winter wheat.

The total corn acreage has remained about the same since 1889. In 1929 corn was grown on 30,234 acres, of which the corn on 18,087 acres was allowed to mature and was harvested for grain, on 6,631 acres was used for silage, on 5,159 acres was cut for fodder, and on 357 acres was hogged off.

Alfalfa, timothy alone, and timothy in mixture with clover, are the principal forage crops. In 1899 alfalfa production in the county was negligible, the Federal census reporting only 30 acres in the crop. The acreage devoted to this crop has rapidly increased in the last decade. This rapid increase is evidence of the recognition of the superiority of alfalfa as forage. It is now grown in all parts of the county, most extensively on the heavier soils. Wild grasses used for hay were cut from 16,635 acres in 1929. Only a small acreage of small grains is cut for hay. A little sweetclover is grown for pasture.

Potatoes, one of the principal crops on the sandier, lighter soils, are an important special crop near Minneapolis, being grown on a large acreage near Osseo. The early varieties are commonly grown, because of the higher price received for them. Some potatoes are trucked to the city markets, and many are shipped to outside markets. During the last 20 years the acreage in potatoes has fluctuated but little, remaining around 14,000 acres.

Commercial fruit growing is carried on extensively in some parts of the county. The 1930 Federal census reports 98,764 bearing apple trees, 7,941 plum trees of bearing age, and 18,247 bearing grapevines in 1929. Raspberries on 798 farms were grown on 1,006 acres and produced 1,528,492 quarts, and strawberries on 616 farms were grown on 388 acres, producing 553,353 quarts. Currants, blackberries, and gooseberries are grown to a smaller extent.

Vegetables for home use are grown on nearly every farm, and near Minneapolis a considerable acreage is devoted to truck crops. In 1929, 385 acres were in asparagus, 146 in snap beans, 860 in cabbage, 877 in melons, 115 in carrots, 350 in onions, 1,831 in sweet corn, 411 in tomatoes, 112 in celery, 180 in cucumbers, 201 in green peas, 85 in spinach, and 52 in squash.

Table 2, compiled from the United States census reports, gives the acreage of the leading farm crops and shows the general trend of agriculture in Hennepin County from 1879 to 1929.

TABLE 2.—*Acreage of principal crops in Hennepin County, Minn., in stated years*

Crop	1879	1889	1899	1909	1919	1924	1929
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Wheat	49,020	11,258	36,117	17,560	29,819	6,925	5,802
Oats	10,594	24,877	27,025	20,941	15,561	20,890	11,031
Corn	16,488	22,337	24,213	23,782	23,264	33,352	30,234
Barley	317	389	708	4,284	3,017	3,689	6,532
Rye	402	1,734	3,672	1,866	5,612	3,775	2,460
Alfalfa	[1]	[1]	30	218	2,369	10,500	17,816
Other tame hay	[2] 26,733	[2] 46,860	26,628	32,560	23,886	16,512	15,937
Potatoes	[1]	9,522	9,567	17,471	14,791	14,011	14,238

[1] Not reported. [2] All hay.

The total number of cattle on the farms of Hennepin County on April 1, 1930, was 43,603. Dairying is the most important agricultural industry on most farms, and, outside the truck-growing districts, nearly every farm carries some dairy cattle. Many are high-grade or purebred animals, of which the Holstein-Friesian, Jersey, and Guernsey are the most popular. Creameries, at which fresh cream is received daily, are located in many convenient places. A large proportion of the whole milk is hauled to Minneapolis or to conveniently located distributing points within the county. The raising of beef cattle is unimportant, the 1930 census reporting very few beef cattle in Hennepin County.

The number of hogs increased from 10,560 in 1880 to 25,291 in 1920, the peak year; since then there has been a decided decrease. Most of the hogs are marketed in South St. Paul. The number of sheep shorn in 1929 was 2,314, and the value of the wool was $5,616.

The number of horses gradually increased between 1880 and 1910 but since then has steadily decreased. Motor trucks in the cities, towns, and on the farms, together with the steadily increasing number of tractors, have been responsible for the rapid decline.

There is scarcely a farm that does not have sufficient poultry to supply home demands and afford a surplus of poultry products for the market. The 1930 census reports the number of chickens raised in 1929 as 502,265, turkeys 6,050, ducks 5,877, and geese 2,680. More than 2,000,000 dozen chicken eggs were produced in the same year. Poultry products are handled largely by local produce stations.

Table 3 shows the number of livestock reported by the Federal censuses from 1880 to 1930, inclusive.

TABLE 3.—*Number of livestock in Hennepin County, Minn., in stated years*

Livestock	1880	1890	1900	1910	1920	1925	1930
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Cattle	14,278	18,786	33,545	34,323	38,105	41,623	43,603
Hogs	10,560	19,214	21,203	21,565	25,291	18,463	9,498
Sheep and goats	9,841	4,904	4,076	4,290	17,642	13,662	3,984
Horses	6,511	8,537	11,458	12,000	11,735	9,720	9,201

The farmers of Hennepin County derive their largest income from the sale of dairy products, the value of which in 1929 was more than $3,250,000. Next in importance are vegetables, including potatoes. The total value of all agricultural products in the county in 1929 amounted to more than $11,000,000, as shown in table 4.

TABLE 4.—*Value of agricultural products by classes in Hennepin County, Minn., in 1929*

Crop	Value	Livestock products	Value
Cereals	$1,327,616	Dairy products	$3,274,560
Other grains and seeds	7,564	Poultry and eggs	1,044,558
Hay and forage	1,329,880	Honey	22,757
Vegetables, including potatoes	2,930,198	Wool	5,616
Fruits	555,947		
All other field crops	25,947	Total	4,347,491
Garden vegetables for home use	133,993		
Nursery, greenhouse, and hothouse products	710,991	Total agricultural products	11,486,062
Forest products cut on farms	116,435		
Total	7,138,571		

The application of manure and the growing of legumes have been the most important methods by which farmers have made an attempt to enrich the soil. The use of commercial fertilizers has increased during recent years, but it is still not extensive. In 1929, about 95 tons of superphosphate were used in the county, 30 tons of phosphate and potash mixtures, and 310 tons of complete fertilizers. The phosphate-potash mixtures, most of which were of the formulas 0:10:20[3] and 0:9:27, were used entirely on the peat soils. The other fertilizers were used on truck crops, potatoes, and corn.

On the majority of farms, all the labor is performed by members of the family, but on the larger dairy farms some extra labor is hired, and many truck farmers hire considerable labor during the growing and harvesting periods.

The average size of farms has decreased from 97 acres in 1880 to 64.3 acres in 1930. The farms range in size from less than 3 acres to more than 1,000 acres, the greater number ranging between 50 and 99 acres.

Approximately three fourths of the farms are operated by the owners, one fifth by tenants, and the rest by managers. More than four fifths of the tenant farmers rent the land for cash, and the others rent on shares. Table 5 gives the status of the farms in Hennepin County from 1880 to 1930.

TABLE 5.—*Status of farms in Hennepin County, Minn., in census years*

Year	Total farms	Average size of farms	Tenant-operated farms	Year	Total farms	Average size of farms	Tenant-operated farms
	Number	*Acres*	*Percent*		*Number*	*Acres*	*Percent*
1880	2,654	97.0	10.1	1920	3,954	68.7	20.2
1890	2,781	91.0	16.0	1925	4,313	57.2	19.5
1900	3,684	80.6	23.5	1930	3,981	64.3	22.1
1910	3,853	73.8	18.7				

[3] Percentages, respectively, of nitrogen, phosphoric acid, and potash.

Most of the farms of Hennepin County are well equipped with modern farm machinery, and on many of them tractors are in general use. In 1927, there were 640 silos, 370 tractors, and 1,212 auto-trucks, according to the State farm census. On many farms electrical power is used—on some farms from local generating units and on others from high-power transmission lines. On many farms windmills furnish power for pumping water, and on others gas engines replace or supplement the windmills.

Good water is readily obtained from wells ranging in depth from 75 to 200 feet. On the sandier soils adjacent to Minnesota and Mississippi Rivers, the wells are shallower. Adjacent to Minnesota River, springs are common, and in some places the water is raised from them by hydraulic rams.

SOILS AND CROPS

Because of the great diversity of the soils of Hennepin County, little difficulty need be experienced in selecting land well adapted to any type of farming common to the locality—general farming, dairying, truck growing, or combinations of these. Dairying is the most extensive type. It has been favored by the suitability of most of the land for grain and forage crops as well as by the proximity of a good market for whole milk. General, or mixed, farming, which ranks second in importance, is carried on in all parts of the county but is more prevalent in the districts more remote from the Twin Cities. Truck farming is extensive in the suburban and adjacent districts. The truck and potato crops are grown largely on the sandy soils. The most extensive soil types are suited to fruit growing. Extensive commercial orchards surround Lake Minnetonka and some of the near-by lakes. Raspberries, strawberries, grapes, currants, and other small fruits do well, and the sale of these fruits constitutes an important source of income for many farmers. According to the Federal census of 1930, the number of farms in Hennepin County devoted to dairying was 1,741; to fruit growing, 246; to poultry, 146; and to truck crops, 266.

The most prominent feature of the landscape, aside from its gently rolling surface, which in some places becomes distinctly hilly, is the large number of poorly drained areas scattered throughout the county. Some of the depressions are occupied by shallow lakes and ponds, some of which have no outlet. Other poorly drained areas are occupied by peat, some are grass and sedge covered, and others support a growth of scrub willow, alder, and tamarack. Much swampy land bordering many of the small streams and drainage ways is somewhat subject to flooding in the spring and at other times of high water. This swampy land is widely distributed but is more extensive in the townships having the heavier soils. Most of the swampy areas are still without adequate drainage, only a small part of the land having been reclaimed. In some swampy places drainage is impossible, because the surface is on the same level as the water in the near-by lakes.

A second striking feature of the landscape is the great amount of land still in forest. These wooded areas, not extensive on any one farm, supply fuel, a part of which is sold and the remainder used for domestic purposes, and provide shelter for grazing livestock. Around

the many beautiful lakes, such as Minnetonka and Independence, much of the native forest remains, adding greatly to the attractiveness of such places.

The soils of Hennepin County have developed on material laid down during the glacial period, when a large part of North America was buried beneath an ice sheet. The ice-borne material, a heterogeneous mixture of rock debris, during the time of deposition, or shortly after, was partly modified by water and wind. The soils have been affected also by the vegetation that has grown on them, in most places a forest of deciduous trees. In the poorly drained areas, water-loving plants have contributed to the accumulation of thick deposits of peat.

The soils that have developed on the various kinds of glacial material differ widely, and to a large extent the physical characteristics of the parent material have been imparted to the soil. Besides the characteristics the glacial material may impart to the soils, other characteristics have resulted from the action of the different soil-forming processes and the intensity with which they have functioned.

In order to group the soils of the county on an agricultural basis so as to show the relationship between the different soils and their uses and productiveness, it is necessary to keep in mind the principal physiographic features of the county. Because of the close relationship that exists between the soils and the geologic formations, they serve as a convenient means by which the soils may be grouped. The most prominent of the physiographic divisions is the broad continuous belt of rolling hilly land that crosses the greater part of the county, a continuation of a terminal moraine that occurs in the southern part of the State and extends into northern Minnesota, passing through Hennepin County. Its continuity in the vicinity of the county is interrupted by Mississippi and Minnesota Rivers, along which are wide sandy plains. These sand and gravel plains represent the second physiographic feature, and the soils formed on them differ widely from those formed on the moraine. These outwash plains were formed at the time the ice of the glacier was melting from the area now occupied by Hennepin County. As the margin of the ice retreated northeastward, streams, heavily laden with glacial debris, spread out over the land uncovered by the ice, dropped the coarser outwash material, and carried the finer material remaining in suspension farther away. As the ice retreated still farther, the streams found new channels, leaving their former beds exposed as dry areas of sand and gravel, with variable surface relief.

The first group of soils will be referred to as soils of the rolling uplands and the second as soils of the smooth sand plains. In the first group are all soil types associated with or related to the morainic material that constitutes the belt of rolling land, and in the second group are soils developed on the sandy outwash plain bordering Minnesota and Mississippi Rivers. More than 75 percent of the total area of the county is included in the first group which is made up of three subgroups, the first consisting of the light-colored well-drained soils, the second of the dark-colored well-drained soils, and the third of the dark-colored poorly drained mineral and organic soils.

The soils of the second group are similarly divided into subgroups as follows: Well-drained soils, and poorly drained soils, all the latter being dark colored.

The soils of the first group are widely distributed throughout the county, but those of the second group are much more restricted and occur mainly adjacent to Minnesota and Mississippi Rivers and to less extent along Crow River.

Table 6 shows the grouping of the main soil types in Hennepin County, Minn.

TABLE 6.—*Grouping of soils in Hennepin County, Minn.*

Group	Subgroup	Soil type
Soils of the rolling uplands	Light-colored well-drained soils	Hayden loam. Hayden sandy loam. Thurston loamy sand. Thurston sandy loam. Thurston sandy loam, shallow phase.
	Dark-colored well-drained soils	Clarion loam. Hayden loam, dark-colored phase.
	Dark-colored poorly drained mineral and organic soils	Webster silty clay loam. Peat. Peat, shallow phase. Muck.
Soils of the smooth sand plains	Well-drained soils	Wadena loamy sand. Wadena sandy loam. Hubbard loamy sand. Hubbard sandy loam. Sparta loamy sand.
	Poorly drained soils	Maumee loam. Maumee sandy loam. Alluvial soils, undifferentiated.

In the following pages the soils of Hennepin County are described in detail and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in Table 7.

TABLE 7.—*Acreage and proportionate extent of the soils mapped in Hennepin County, Minn.*

Type of soil	Acres	Per-cent	Type of soil	Acres	Per-cent
Hayden loam	93,952	26.0	Hubbard loamy sand	26,944	7.4
Hayden sandy loam	13,312	3.7	Hubbard sandy loam	7,488	2.1
Thurston sandy loam	13,824	3.8	Sparta loamy sand	2,496	.7
Thurston sandy loam, shallow phase	12,544	3.5	Maumee sandy loam	3,712	1.0
Thurston loamy sand	5,248	1.4	Maumee loam	3,520	1.0
Hayden loam, dark-colored phase	21,312	5.9	Alluvial soils, undifferentiated	4,736	1.3
Clarion loam	42,688	11.8	Steep broken land	1,792	.5
Webster silty clay loam	21,824	6.0	Unclassified city land	16,768	4.6
Peat	50,496	14.0	Beach sand	384	.1
Peat, shallow phase	4,416	1.2	Made land	192	.1
Muck	1,664	.5			
Wadena sandy loam	4,608	1.3	Total	361,600	
Wadena loamy sand	7,680	2.1			

SOILS OF THE ROLLING UPLANDS

LIGHT-COLORED WELL-DRAINED SOILS

The eastern part and a large portion of the southern part of Hennepin County have light-colored surface soils which have developed under a mixed hardwood forest. These soils cover the greater part of the county, some of them occurring in every township. All are well drained, the surface relief ranging from gently rolling to hilly. In several localities, as in southeastern Maple Grove Township, the surface relief ranges from sharply rolling to hilly, and in

the southern part of the county some areas have very sharp relief. Most of the soils of this subgroup are well suited to general farming, as they are in general free of stone, and only a comparatively small part of them is so hilly as to interfere with the use of modern farm machinery. The principal type of agriculture is dairying, and a large number of well-bred herds of cattle are on the farms. The soils around the lakes, where much fruit is grown, are chiefly soils of the Hayden and Thurston series.

Hayden loam.[4]—Hayden loam has a light-gray or gray surface soil which ranges in texture from fine sandy loam to loam. The upper part of the subsoil ranges from light yellowish brown to yellowish brown and when dry is somewhat hard, but when moist it is plastic and sticky. The fine texture of the subsoil allows it to retain moisture well. The deeper part of the subsoil consists of friable light yellowish-brown sandy clay loam or clay loam containing considerable lime. In areas in which the surface is more rolling, the soil has a tendency to wash, the finer material being carried to the lowlands, leaving the brown heavier upper subsoil layer exposed. Therefore, the lower slopes of many of the steeper hills have a finer-textured surface soil. In some places erosion has formed small gullies, but sheet erosion has been more damaging.

Most of Hayden loam has a sufficiently coarse-textured surface soil that, after being saturated with water, dries out rather rapidly, thus allowing the land to be worked early in the spring. With the exception of the well-drained sands, this soil is among the first in the county to dry in the spring and accordingly is the first to be worked. It is naturally productive.

Tame hay, mainly alfalfa, is the leading crop in point of acreage. At present about one seventh of the cropped land is devoted to it, and the acreage is increasing yearly. Clover alone, or mixed with timothy, is also grown but on a smaller acreage than alfalfa. Corn is the leading grain crop, followed by oats and barley. Barley is sown on the more productive fields, and oats and rye are usually sown on the less fertile spots. Some wheat, of both fall and spring varieties, is grown on a small acreage. Some potatoes and truck crops are grown as cash crops. Nearly all the grain is fed on the farms, part of the corn being used as fodder and part as silage. Most of the land devoted to pasture consists of wooded and hilly tracts.

Hayden sandy loam.—Hayden sandy loam is closely related to Hayden loam, and the agricultural practices on it differ but little from those followed on the loam. Hayden sandy loam is restricted to areas with sharper relief, its surface relief ranging from rolling to hilly. Many of the slopes are steep and either terminate in small inclosed basins or in larger peat-covered swamps. In the north-central part of the county, this soil lies in close proximity to the sandy terrace soils, but in Eden Prairie Township it is surrounded by areas of Hayden loam. Smaller tracts are distributed over the rest of the county, and the eastern part of Lake Minnetonka is bordered by this soil.

The surface soil of Hayden sandy loam is light-gray or grayish-brown sandy loam to a depth ranging from 8 to 12 inches. It is

[4] An area of soil mapped as Hayden loam in Hennepin County joins along the county line with soil mapped as Miami loam in Anoka and Ramsey Counties. This apparent discrepancy is due to further study of the Miami soils, which has restricted this series to browner soils lying farther south in the United States and has led to the recognition of a separate series (Hayden) to include similar but grayer soils of this section of Minnesota.

underlain by grayish-yellow or yellowish-brown crumbly sandy loam, most of which has a red cast when moist. The deeper part of the subsoil in most areas is grayish-brown or yellowish-brown sandy loam or sandy clay, mixed with considerable coarse sand and gravel. On many of the cultivated slopes the surface soil has been removed by erosion, exposing the brown subsoil. Hayden sandy loam is variable in the texture of both the surface soil and subsoil. In some places the surface soil consists of a shallow layer of sand resting on a mixture of sand, gravel, and finer material, but on the lower slopes the coating of fine material is much thicker, having received the wash from the higher land.

Because of its rougher surface not nearly so much of this soil is under cultivation as of Hayden loam, and a comparatively large part of it is devoted to wood lots and permanent pastures. Under favorable rainfall conditions and good farm practices good yields are obtained, but the soil cannot withstand prolonged periods of drought so well as the heavier Hayden loam.

Thurston sandy loam.—Thurston sandy loam and its shallow phase occupy areas that are similar in surface relief and surface drainage to those occupied by Hayden sandy loam. These soils, together with Thurston loamy sand, occupy some of the rolling land in the southern part of the county, although in Eden Prairie Township some areas are level. Thurston sandy loam occurs in a more or less continuous belt in Minnetonka Township, in the western and southern parts of Eden Prairie Township, and around the village of St. Louis Park. Another area extends from Medicine Lake to the eastern edge of Lake Minnetonka. Bodies of this soil are surrounded by areas of Hayden soils and in some places by the sand-plains soils.

Thurston sandy loam has a dark brownish-gray surface soil which ranges in texture from loamy sand to loam. It is underlain by beds of sand and gravel, some of which are stratified. The depth of the finer material overlying the sand and gravel is extremely variable, ranging from a few inches to more than 3 feet. In some places the coarse subsoil is within a few inches of the surface, and only a few rods away it may be several feet below. These extreme variations in the depth to the gravelly and sandy substratum cause marked differences in the productiveness of the soil. In the hilly areas, erosion is severe on many of the slopes, and in some places the sand and gravel are exposed at the surface.

Crop yields differ more widely than on the Hayden soils. As with Hayden sandy loam, much of the rougher land is left in wood lots and permanent pastures. Thurston sandy loam is not important agriculturally, because of its rough surface and small extent. Although no large farms are located entirely on this and the other Thurston soils, these soils form a part of many farms. A large part of the Thurston soils lies in industrial localities and in plotted suburban tracts. Where the surface is not too rough and the fine soil is of fair depth, Thurston sandy loam is moderately productive if handled with ordinary care.

Thurston sandy loam, shallow phase.—The shallow phase of Thurston sandy loam has a shallower surface cover overlying the gravel beds than has typical Thurston sandy loam. The two soils are about equal in extent. The shallower soil is associated with land having rougher surface relief.

In the suburban districts, large gravel pits are located on areas of the Thurston soils, some of the gravel being washed and hauled to Minneapolis for building purposes. Around St. Louis Park and Edina, typical Thurston sandy loam predominates, but in eastern Minnetonka and southern Eden Prairie Townships, the shallow phase is the more prominent. The shallow phase of Thurston sandy loam is very droughty and requires liberal fertilization to produce yields that will justify the labor expended.

Thurston loamy sand.—Thurston loamy sand, which occurs only in small patches throughout the area occupied by Thurston sandy loam and its shallow phase, differs from Thurston sandy loam in that the surface soil is sandier and has a tendency to drift where exposed to the sweep of the winds. Because of its small total area, very sandy texture, and rough surface relief, Thurston loamy sand is of very little agricultural importance. The large area around Calhoun and Harriet Lakes has a somewhat finer texture than the smaller areas along Minnesota River in the extreme southern part of the county. This area, however, has little agricultural significance, since it is largely urban land in the city of Minneapolis.

DARK-COLORED WELL-DRAINED SOILS

From the eastern part of the county to the western part the surface soils become gradually darker. This is more noticeble in the spring just after the land has been prepared for seeding, at which time the soils are usually moist and appear black or very dark gray. The range line separating Plymouth Township from Orono and Medina Townships, and Maple Grove Township from Corcoran Township, roughly represents the line dividing the dark-colored soils from the light-colored soils, though patches of dark-colored soils lie east of this line and patches of light-colored soils are west of it. Toward the west, however, the soils become increasingly darker, the dark-colored layer thicker, and the texture finer. They gradually assume the characteristics of the typical grassland soils of the western part of the State. Soils of this subgroup occur, for the most part, on the broad smoother areas of the county and are best developed in parts of Corcoran, Greenwood, and Independence Townships. However, they are fairly well developed in places where the relief is sharper, as in parts of Minnetrista Township which is one of the most rolling areas in the county. These dark-colored soils belong to the Clarion series, of which one type, Clarion loam, is shown on the map. A dark-colored phase of Hayden loam, which represents the transitional soil lying between the lighter-colored Hayden soils and the darker-colored Clarion loam, is the other member of this subgroup. Agriculturally, the difference between Hayden loam and Hayden loam, dark-colored phase, is not great.

Hayden loam, dark-colored phase.—Hayden loam, dark-colored phase, has in general the same characteristics as Hayden loam, except that the surface soil is darker and deeper and rests on slightly finer textured compact yellowish-brown clay loam which overlies a friable open silty clay loam subsoil. In most places the surface soil is somewhat finer textured, is smoother when rubbed between the fingers, and contains less grit than the surface soil of typical Hayden loam. This dark-colored soil is somewhat harder to handle, that is, it requires more power and can not be worked under so wide a range of moisture conditions as typical Hayden loam.

Clarion loam.—Clarion loam has a distinctly dark-colored surface soil from 8 to 12 inches thick. It is very dark grayish brown or black, friable, and finely granular. In some places the dark surface layer is shallower and does not have the characteristic granular structure. The surface soil is underlain by grayish-brown silty clay loam which grades into dark-brown or slightly yellowish brown sandy clay or silty clay loam. Beneath this, at an average depth of 20 inches, the subsoil is lighter yellowish-brown friable silty clay loam which is very retentive of moisture and very plastic when wet. Lime carbonate in appreciable quantities is present in this lower layer, but in general none occurs above it. Variations from the typical soil are of common occurrence and consist chiefly in the depth of the dark-colored material and in the color and the lime-carbonate content of the subsoil. The texture, however, remains fairly constant, except that on the smoother areas the subsoil is finer, with the result that percolation of water is less rapid and the soil does not dry out so early in the spring.

Clarion loam is a fertile soil, and its productivity may be maintained under less careful management than that of the Hayden soils. Most of the crops grown are fed on the farm. Corn occupies a larger acreage of the cropped land than any other crop, being followed in acreage by tame hay, oats, barley, fall-sown and spring-sown wheat, and winter rye, only a small acreage of rye being grown. Alfalfa and mixed clover and timothy are the principal hay crops. The acreage devoted to alfalfa is considerably in excess of that devoted to other tame-hay crops, more than one seventh of the cropped land being devoted to it. Only enough potatoes are produced to meet domestic needs. A small part of almost every farm is utilized for growing fruit, berries, and vegetables, and a considerable proportion of the land is in pasture and wood lots.

DARK-COLORED POORLY DRAINED MINERAL AND ORGANIC SOILS

This subgroup includes primarily the mineral soils occupying depressions and low-lying areas in the glacial-till plains. The mineral soils are limited to a single type, Webster silty clay loam. The organic soils of the glacial-till plains, the outwash plains, and the bottom lands of variable composition, along the streams, most of which are flooded at various times of the year, are included.

Webster silty clay loam.—Webster silty clay loam has a deep dark-gray or black surface soil, ranging in texture from sandy loam to clay loam. In some places it is more than 20 inches thick, but it averages about 12 inches. The upper part of the subsoil is either dark-gray or light-gray material, more or less stained with blotches of orange, yellow, and red. The subsoil material is largely clay loam, which is sticky when wet and somewhat impervious to percolating water. Owing to its position in depressions, surrounded by upland soils with prominent slopes, this soil has received a coating of fine silty material carried down by running water, with the result that around the outer edges of the depressions a layer of fine soil material of variable thickness covers the surface.

Areas of this soil are scattered throughout areas of the Hayden, Thurston, and Clarion soils. They range in size from less than 1 acre to more than 160 acres and comprise a fairly large total acreage. Many of the areas are only potholes, ranging from less than 1 acre to about 3 acres in extent, and they cannot be shown on the soil map

because of their small size. A large proportion of this soil borders the peat bogs as a narrow fringe, wholly or partly surrounding them. A part occurs along small drainage ways, presenting a very irregular outline, and some areas occupy small inclosed basins without natural outlets. Nearly every large farm includes some of this soil, and as so much of it occurs in small areas, it receives no special treatment or handling but is farmed in the same manner as the adjacent land. A better-drained variation of this soil, not differentiated on the soil map, occurs in several places. One area, including about a square mile, is in Orono Township, west of the village of Long Lake. This area is flat and lies at about the same elevation as the surrounding Clarion soils.

Only a small percentage of the Webster soil is under cultivation, owing to its poor natural drainage. All areas require artificial drainage, which is the first step in the reclamation of this land, and some of the larger areas would require extensive drainage projects which would affect a large district or community. Wild grasses grow luxuriantly on areas of this soil that are not permanently saturated with water, and much wild hay is harvested. On some of the drier tracts, timothy, redtop, and alsike clover have been seeded or have accidentally become sown with the wild grasses.

Peat.—The organic soils, commonly known as peat and muck soils, are composed of plant remains that have accumulated in former lakes and ponds and along sluggish creeks. They have a restricted agricultural use and must be handled differently from the mineral soils. The organic soils occur in all parts of the county, both on the river valley plains and on the glacial-drift uplands. The depth of the peat deposits ranges from 1 foot to more than 20 feet, but very little of the peat is less than 2 feet thick. Most of the peat bogs are covered with sedges and wild grasses, and others are occupied by tamarack, dwarf birch, and willow.

Peat, shallow phase.—Areas of peat in which the organic deposit is less than 2 feet thick have been correlated as peat, shallow phase. It occurs only in some of the smaller depressions.

Muck.—In Minnesota all the organic soils are commonly called peat, but in the mapping of the soils of Hennepin County the black more decomposed organic material has been mapped as muck. In many places muck contains more mineral matter which has been washed in or blown in on the bog and become mixed with the plant remains. Muck ranges in thickness from 6 inches to 2 feet. It occurs only in some of the small depressions and along some of the streams, occupying a total of less than 1 percent of the area of the county. Its handicaps and the methods of handling it are similar to those of the less decomposed material mapped as peat.

SOILS OF THE SMOOTH SAND PLAINS

The soils of this group are extensive along Mississippi and Minnesota Rivers and less extensive along Crow River. Because of their sandy texture, they fall in a group in which the soils are agriculturally different from the soils of the rolling uplands of the glacial-till plains. The principal differences between the soils of these two groups is that the soils of the second group have sandy surface layers and subsoils of sand, gravel, or a mixture of sand and gravel; in relief the areas

are smoother, less dissected, and lack the extensive forest cover prevalent on most of the uplands.

The most extensive continuous area of these soils begins near Mississippi River about 3 miles southeast of Dayton and follows the river to a point near the northern city limits of Minneapolis. At Champlin the belt is not more than 1½ miles wide, but near Osseo it reaches a maximum width of about 6 miles and from there gradually narrows to about 3 miles. The sand plain is interrupted for a few miles north of Minneapolis but begins again within the city limits and follows Mississippi River to its junction with the Minnesota at Fort Snelling. Similarly, it borders the Minnesota to a point beyond the county boundary. Through the last 10 miles its width is only about 1½ miles, but just south of the confluence of the Minnesota and the Mississippi it ranges from 4 to 5 miles in width. The terraces lie from 10 to 20 feet above the water close to Mississippi River, but in places at the western edge of the sand plain are more than 60 feet above the river. The slope is very gradual and in marked contrast to the terrace plain along Minnesota River, where a sharp rise of more than 100 feet occurs within a short distance. Beyond the sharp escarpment, the sand plain is smooth but gradually rises as the heavier till plain is approached.

The sand plain in some places is dissected by numerous small streams and drainage ways, and a large area is occupied by swampy land, much of which is covered by peat. The lower part of the southern valley plain is cut by Purgatory Creek, a small stream which has eroded a deep gorge through the sand and gravel into bedrock. Its source is in the till plain to the northwest, and probably it was at one time the outlet of Lake Minnetonka. It is now largely fed by springs.

The soils of the sand plain are placed in two subgroups, the first including the well-drained soils and the second the poorly drained soils. The members of both subgroups are very irregularly distributed, soils with fair or poor drainage being closely associated with the better-drained soils.

WELL-DRAINED SOILS

The well-drained soils occupy the greater part of the sand plain and, on the basis of their soil characteristics, may be subdivided into three soil series, differing in agricultural value, the Wadena, the Hubbard, and the Sparta. The Wadena soils have dark-colored sandy surface soils, well-developed heavier subsoils, and sand and gravel substrata. The Hubbard soils differ from the Wadena soils in the character of both surface soil and subsoil, the surface soil consisting largely of assorted fine sand and lacking the heavier upper subsoil stratum which is so pronounced in the Wadena soils. Coarse sand and gravel, not present in many places in the Hubbard subsoils, are very common in the Wadena soils. Sparta loamy sand consists of fine sand that has been subjected to wind movement and has topographic features characteristic of sand dunes.

The soils of the Wadena series predominate in the northern part of the county, whereas in Richfield and Bloomington Townships, in the southern part, the Hubbard soils predominate.

In some places the Wadena soils have developed under a forest of scrub oak, aspen, and birch, but large areas were originally nearly treeless or supported only stunted trees and considerable brush.

A fairly large acreage of all these sandy soils is devoted to truck and special crops. In Brooklyn Township more than one third of the cropped land is used for potatoes; in Champlin, one fifth; in Crystal Lake, one fifth; and in Bloomington, about one seventh. Corn ranks next in acreage, followed by tame hay and oats. Some winter rye and wheat are also grown. The principal tame-hay crops are alfalfa and clover mixed with timothy. The alfalfa acreage is increasing yearly, and at present this crop occupies a larger acreage than any other hay crop. Most of the sandy soils, after liming, are well suited to alfalfa, and in years of liberal rainfall the yields are satisfactory.

Many small truck farms, on which vegetables only are produced, are located on these soils, and on others some truck crops and fruit are grown in connection with general farming and dairying. On the larger farms, a fairly large acreage is devoted each year to potatoes which are the principal money crop. The greater part of the 14,000 acres in potatoes in Hennepin County in 1929 represented soils of the sand plain. On some farms a much smaller acreage is devoted to cabbage, tomatoes, onions, and other vegetables.

Many fields of the sand-plain soils are heavily fertilized with manure brought in from the stockyards of South St. Paul. Rye, which is used extensively as a green-manure crop, is planted in late summer and plowed under early in the spring in preparing the seed bed for potatoes.

Wadena sandy loam.—The more characteristic soil of the Wadena series is Wadena sandy loam which has a dark grayish-brown or dark-brown sandy loam surface soil ranging from 8 to 14 inches in thickness. Underlying this and separated from it by a rather sharp line of demarcation is a dark chocolate-brown or reddish-brown coherent heavy sandy loam layer which, in turn, gradually merges into a gravelly sandy layer mixed with some clay. All the material comprising the soil consists of unassorted sands mixed with some fine and coarse gravel which is more abundant in the lower part of the subsoil. In some places the sandy material has been deposited in a layer of variable thickness over the boulder clay of the drift plain, which in some places is less than 3 feet below the surface.

The surface relief of Wadena sandy loam is gently undulating, in some places nearly flat. Drainage is good because of the openness of the soil. The areas, however, are dotted with slight depressions, most of which lie only a few feet lower than the surrounding land. These collect the water that runs off the slightly higher land, thereby retarding the drainage.

A large proportion of Wadena sandy loam is under cultivation, and truck farming, together with the growing of potatoes, mainly of the early-maturing varieties, is extensively engaged in. Both Wadena sandy loam and Wadena loamy sand are well adapted to truck and special crops because of the ease with which these soils are worked and the rapidity with which they warm up in the spring.

Wadena loamy sand.—Wadena loamy sand is similar in general characteristics to Wadena sandy loam. The chief difference between the two soils is in the sandier texture of the surface soil and subsoil of the loamy sand. The surface soil is, in general, not so dark colored, the moisture-holding capacity is somewhat less, and the productivity, except for some of the truck crops, is probably not so great.

Hubbard loamy sand.—The Hubbard soils occupy positions having more pronounced relief than the Wadena soils, and the material consists of finer more assorted sands. Hubbard loamy sand, the more extensive of the Hubbard soils, is characterized by the uniformity of the sandy material from the surface downward. The surface soil consists of uniform dark-brown or yellowish-brown loamy sand which overlies a brown or dark yellowish-brown subsoil of similar material, though somewhat more fine and firmer. This layer, in turn, grades into mellow loose and incoherent fine sand and medium sand. As depth increases, the sand grains become slightly coarser.

The surface relief of Hubbard loamy sand ranges from undulating to gently rolling, and all areas have good surface drainage. Water does not stand on the surface for any great length of time, as it percolates rapidly through the soil. As with the Wadena soils, a comparatively large area of the Hubbard soils is devoted to truck crops and potatoes, though some is used for general farming and dairying.

Hubbard sandy loam.—Hubbard sandy loam differs from Hubbard loamy sand in that the surface soil has a finer texture and a somewhat darker color. This soil is inextensive. It occurs in small patches associated with Hubbard loamy sand.

Sparta loamy sand.—Sparta loamy sand differs from the Wadena and Hubbard soils in having a lighter-colored surface soil, a poorer development of soil horizons, and an incoherent and loose open surface soil and subsoil. It is subject to drifting. This soil is developed on elongated ridges with rather sharp but smooth slopes, on knolls, and on slightly elevated areas with gentle slopes. Nearly all of it occurs in Brooklyn, Hassan, and Champlin Townships. The land is droughty.

POORLY DRAINED SOILS

In the aggregate the poorly drained mineral soils of the sandy plains comprise a comparatively large area. They are more extensive and occupy larger areas adjacent to Mississippi River than they do along Minnesota River. Associated with them are the peat and muck deposits, most of which are grass and sedge covered.

These poorly drained soils occupy two general positions as follows: (1) Areas that are nearly level or slightly depressed, where natural drainage is only fair; and (2) more sharply depressed areas in which natural drainage is entirely lacking or is very poor. All these soils have dark-colored surface soils, and they contain a large quantity of organic matter. The better-drained areas are more extensive than those of extremely poor drainage, and they occupy situations along natural drainage ways and slight depressions in the upland, in which surface drainage is effected through some natural outlet. In such places most of the surplus water can escape more quickly than by the slow process of seeping through the subsoil. Sometimes, however, seeping takes place very slowly, and the land is frequently under water for short periods, as in the spring after the snow has melted and after heavy rains. The soils of the more poorly drained areas are waterlogged much of the time, and some areas, because of their occurrence in inclosed basins, remain saturated throughout the year. In some places the land has been artificially drained, and this allows it to be utilized for the production of tame hay and other crops. A large

proportion of the better-drained land is under cultivation, but most of the very wet land remains unreclaimed. A fairly large acreage is devoted to tame-hay meadows, though wild hay is still harvested from a larger acreage.

Maumee sandy loam.—Maumee sandy loam has a dark-colored surface soil ranging in color from very dark gray to black, in depth from 10 to 16 inches, and in texture from loamy sand to sandy loam. The upper part of the subsoil is brownish-gray sandy clay or clay loam, highly stained with bright-orange, yellow, and reddish-yellow blotches. The deeper part of the subsoil is grayer, the blotches less numerous, and the texture in most places coarser. Most of the material is sand, with some gravel, and in some places it is sandy loam. At different depths below the surface, thin horizontal bands of deposited fine clay or marl are present in many places.

Maumee loam.—Maumee loam is less extensive than Maumee sandy loam, from which it differs chiefly in the heavier or more loamy texture of the surface soil. The subsoil is similar to that of Maumee sandy loam, with perhaps more clay and silt and a small proportion of sand. The substratum is variable, ranging from moderately heavy to sandy water-laid materials.

Alluvial soils, undifferentiated.—Minnesota River has an extensive flood plain along its entire course through Hennepin County. The soils comprising it are extremely variable in composition, the texture ranging from sand to silt, and they include considerable peat. Similar low-lying soils, occupying smaller tracts, border parts of Minnehaha, Shingle, and Bassett Creeks. Because of the great variation of these soils within short distances, they all have been designated as alluvial soils, undifferentiated, in order to distinguish them from the better-drained more uniform soils. Immediately adjacent to Minnesota River the land lies several feet above the river, has fair or good drainage, and some is farmed. Beyond this fringe, which ranges in width from 10 to 100 rods, the land lies much lower and is swampy, water standing on it in places throughout the year. When the river is high these areas form shallow lakes, in which much aquatic vegetation grows. Most of these swampy soils support wild grasses, sedges, willow, and alder, and in the drier open situations some wild hay is harvested.

MISCELLANEOUS SOIL MATERIALS

Steep broken land.—Steep broken land includes the steep slopes which form the escarpments bordering the Minnesota River terrace lands. The material is variable, ranging from loose sand to glacial till. Its agricultural use is limited by its sloping surface, and it is largely in woodland and pasture.

Unclassified city land.—Unclassified city land includes the area covered by the city of Minneapolis. Such land is covered by buildings or has been so disturbed by building operations, grading, and filling, and it was so difficult to ascertain the natural soil characteristics, that it was considered inadvisable to undertake to indicate the various soil types which may have occupied the area under natural conditions.

Beach sand.—Beach sand consists of small areas of loose sand surrounding some of the present and former lake beds or occurring along old stream channels.

Made land.—Made land consists of filled-in areas that have been built up to higher levels by the hauling in of material from other sources. It is confined mostly to lake-shore property and to tracts in urban and suburban territory.

AGRICULTURAL METHODS AND MANAGEMENT

In considering the agriculture of Hennepin County five groups of soils may be recognized as follows: (1) Those of medium texture in both surface soil and subsoil and having good natural drainage; (2) soils with sandy surface soils and subsoils, also with good natural drainage; (3) variable soils of the Thurston series with good natural drainage; (4) mineral soils of poor natural drainage; and (5) peat, together with associated tracts of muck, all having poor natural drainage.

The first group includes Hayden loam, Hayden loam, dark-colored phase, Hayden sandy loam, and Clarion loam, all of which are productive soils well supplied with lime. Crops on these soils do not suffer from drought except during prolonged dry periods. Hayden sandy loam, because of a somewhat coarser texture of the subsoil, is the least retentive of moisture of the soils of this group. The Clarion soils are somewhat more difficult to work than the Hayden, being of finer texture and firmer consistence; accordingly more power is needed for farm machinery in working them. Stones on the surface, or embedded in the upper part of the soil, which are a common source of annoyance on many soils similar in origin to those of Hennepin County, are comparatively scarce, but on some small scattered tracts of the Hayden soils a considerable number of stones were originally present. The Clarion soils have a darker surface soil and are somewhat richer in organic matter and nitrogen than the Hayden. Nitrogen is the plant-food element which more frequently limits crop yields of nonlegumes on the soils of this group, especially on the knolls and hillsides where much of the darker surface soil has been removed by erosion. In such places a nitrogen fertilizer usually produces a very marked increase in the yield of grain.

On these soils dairying is the principal type of farming, and large quantities of concentrates are fed. Second in importance is mixed farming, with considerable attention given to fruit growing in a few districts, especially around Lake Minnetonka. Apples, raspberries, and strawberries are the most important fruits.

Hay is the leading crop in point of acreage, followed in order by corn, oats, barley, wheat, and rye. Not much truck is grown. About one third of the crop land is devoted to hay, and of this alfalfa occupies more than half the acreage, and the common clovers, usually mixed with timothy, are grown on the rest. Not much sweetclover is grown, and it is used only for pasture. The acreage of alfalfa is steadily increasing from year to year. In each of eight townships in 1929 more than 1,000 acres were devoted to alfalfa.

The agricultural methods in use on all these soil types are much alike. The usual practice is to follow loosely a rotation of corn, small grain, and clover and timothy, but most of the farmers do not adhere rigidly to any standard rotation on all their fields. They may grow two crops of small grains in succession, the clover and timothy hay may be left for 2 years or more, or potatoes may constitute a part

of the cultivated crop. Alfalfa is not plowed down until the stand becomes thin. Meadow and pasture are usually followed by corn or potatoes, the sod being broken in early fall. Much of the corn is planted on land previously in small grain. The cornland is usually plowed in the fall or in the spring, before seeding with small grains.

Commercial fertilizers have been used but little on these soils, with the exception of some complete fertilizer on cornland. Judging from trials on similar soils in neighboring counties, it is probable that on some of the fields phosphate will cause a marked increase in the yields of hay, small grains, and corn.

The second group includes all the soils of the Wadena, Hubbard, and Sparta series mapped in Hennepin County. Most of these soils are not well supplied with lime for alfalfa and sweetclover, and all are naturally low in organic matter and nitrogen. Nitrogen is the plant food which first becomes deficient in all these soils, and the lack of it commonly limits the yields of small grains, corn, potatoes, and other cultivated crops, even in seasons of favorable rainfall. The soils have a low moisture-holding capacity, causing crops to suffer from drought during dry periods, and a lack of moisture is the factor which most frequently limits crop yields. They are all subject to drifting.

The principal type of farming on these soils consists of potato and truck growing, followed in importance by dairying. Some attention is given to small fruits, chiefly raspberries and strawberries. The truck crops include carrots, radishes, asparagus, peas, onions, cabbage, cauliflower, tomatoes, beans, cucumbers, melons, squash, and sweet corn.

The principal field crops, in order of acreage, are potatoes, corn, hay, oats, and rye. Alfalfa now occupies more than half the tame-hay land. Some winter wheat is sown, and in favorable seasons, on land in a high state of fertility, good yields are obtained.

In general, little or no attempt has been made to follow a systematic crop rotation on these soils. On some of the farms, potatoes have been grown year after year in the same fields. Only early varieties are grown, and they are planted as soon as possible and harvested early. The general practice is to seed winter rye very soon after the potatoes have been removed. The rye usually covers the ground so well that it prevents drifting of the soil during winter and early spring. Only a small part of this crop is allowed to ripen grain, most of it being plowed under as green manure for the following crop of potatoes or corn, a small part having been first pastured.

Until recently the application of manure and the growing of a very small acreage of red clover were the only means employed to increase the fertility of these soils. Manure is still used very extensively, but during the last few years fairly large quantities of complete commercial fertilizers have been used for potatoes and truck crops. Formerly a large quantity of stable manure was hauled from Minneapolis, but with the decline in the use of horses in the city this supply failed. In 1919 an association of farmers was formed, which contracted for the manure from the stockyards of South St. Paul. Most of the manure taken by the northern sandy districts around Osseo and Robbinsdale is shipped by rail, but most of that going to the southeastern sandy district is hauled by truck directly from the stockyards. Many of the potato growers near Osseo feed lambs during late fall

and winter, for the sake of the manure produced. Most of the farmers do not purchase the sheep but simply feed them on contract with the owners, who furnish the hay, mill screenings, and grain, and the farmers furnish the straw for bedding, most of which they must buy. In return for their labor and the straw they get the manure. This manure, as well as much of that from South St. Paul, is spread during winter and early spring, on many farms on winter rye and is plowed under.

The most common fertilizers used are 4:8:6, 2:14:4, 2:14:14, and 2:12:12 mixtures. For potatoes and corn these are applied by means of an attachment on either the planter or the cultivator. Where the cultivator attachment is used, the application is either made by blind cultivation soon after planting or at the first cultivation after the plants are up.

On the Coon Creek sand experimental field of the University of Minnesota, located in Anoka County on soil very similar to the soils of this group, it has been shown that the land is greatly improved for succeeding crops when alfalfa is grown for several years, even though all the growth be removed as hay. The beneficial effect of growing alfalfa for 3 or 4 years, using neither manure nor commercial fertilizer, has been greater than the effects resulting from the application of as much manure as could be produced by feeding all the crops grown on the land in the course of a 3-year rotation, including 1 year in clover.

On most of these sands, when in a fair state of fertility, good stands and satisfactory yields of alfalfa can be obtained without liming, provided inoculation has been effected by applying a ton or more an acre of soil from an established field of alfalfa or sweetclover. On all except the least lime-deficient fields, however, liming increases the yields, especially in the first crop year, even where the land has been satisfactorily inoculated by the above method. It is less difficult to obtain stands of alfalfa after liming, and, in a season when weather conditions are unfavorable for the young plants, the stand may be a success on the limed part of the field and a complete failure on the unlimed part. On land that has been limed well in advance of seeding, the use of commercial cultures of alfalfa bacteria are as effective as the heavy application of soil from an established field of alfalfa or sweetclover.

Ground limestone from Minneapolis and St. Paul is used almost exclusively as liming material, and from 2 to 3 tons an acre is the usual application. Marl of good quality occurs in many places in Hennepin County, but little is used because ground limestone is so cheap and the marl is usually much more difficult to spread. Whichever form of lime is used, its beneficial effect is much increased by thoroughly mixing it with the soil and by applying it several months before seeding the alfalfa. It is usually still more effective if put on a year in advance, and it may be applied 2 or 3 years before seeding without any loss of beneficial effect. The advantage of the early application shows up most strongly whenever conditions are made difficult for the young alfalfa plants, as by dry weather or the use of a nurse crop. In general, the best time to apply lime is immediately after plowing, as the disking and harrowing necessary to prepare a good seed bed serves to thoroughly mix the lime with the soil. When applied to corn stubble or potato land to be seeded without plowing, the lime should be thoroughly disked in.

Alfalfa may be seeded in the spring with the grain crop (barley, wheat, or oats), or it may be sown alone in either spring or summer. Whichever method is used, it is very important that the seed bed be both firm and moist at the time of sowing the alfalfa. It is easier to get a good stand when the land is in a good state of fertility. On land sufficiently limed in advance, a good stand can ordinarily be obtained with a nurse crop of spring grain, except in an unusually dry season. Under such unfavorable conditions, much better stands of alfalfa have been obtained with barley and spring wheat than with oats, and with oats failures have been less frequent than with winter rye. When the lime has not been applied well in advance, seeding without a nurse crop is the surer method, keeping the land clean, making it firm with a corrugated roller or cultipacker, and seeding it as soon as possible after a good rain, preferably between June 15 and July 20.

Sweetclover is more sensitive to lack of lime in the soil than alfalfa, and on lime-deficient soils the use of a heavy application of inoculating soil has not proved effective. This crop requires the same seedbed conditions as alfalfa, is similarly affected by small grains sown with it, and on these sandy soils in dry seasons usually gives a poorer stand than does alfalfa sown beside it at the same time, on similarly prepared land, and with the same small grain.

Red clover, although less sensitive than alfalfa and sweetclover to lack of lime, does better on the lime-deficient sands after they have been limed; but even then the difficulty of obtaining a stand is so much greater than with alfalfa and sweetclover, and even when a stand has been obtained the yields are usually so much lower, that the use of red clover on these sandy soils is not to be recommended.

The Thurston soils are characterized by extreme variability within short distances. Even small tracts may consist partly of hilly ground or knolls, with a shallow surface soil and sand and gravel close to the surface, and partly of more level land, with a deeper layer of dark surface soil and loam to a depth of 4 or more feet. Where the sand or gravel is close to the surface, the soil is droughty and of low productivity; but where the fine material is deep, the soil is retentive of moisture and produces well.

These soils occupy only a comparatively small total area, and a large part of this is in industrial districts and in plotted urban and suburban tracts. Many small holdings are mainly in garden lots, small truck and fruit farms, and poultry ranches. The holdings of farm size are used chiefly for truck growing, although a few are devoted to dairying and mixed farming.

The use of manure and commercial fertilizers on Thurston soils is similar to that on the well-drained sands.

The group of poorly drained mineral soils includes members of the Maumee and Webster series. Some areas are located in basins with no outlets and others on more or less level low ground with inadequate natural outlets. Only a small part of the Webster and the wetter areas of the Maumee soils have been provided with good drainage and brought under cultivation, but a rather large part of the better-drained areas of the Maumee soils has been drained and is in crops. In some of the undrained meadows timothy, redtop, and alsike clover have been seeded, and in others these plants have been

introduced accidentally and are now growing with the wild grasses. These soils are well supplied with lime and are rich in organic matter and nitrogen. Therefore, very little manure or fertilizer has been used on them. On the margins of some of these poorly drained areas, where phosphate has fallen, incident to its application to the adjacent well-drained land, a marked increase in the growth of the grass has been observed. Wherever sufficient drainage can be provided, this lowland offers an opportunity for the development of good pastures.

The organic soils, peat and muck, in their natural condition are used only as wild meadows, except for an occasional poor pasture, as they are too wet to allow cultivation. Not more than 3 percent of these soils in Hennepin County has been drained and brought under cultivation, mainly for potatoes and truck crops, and a little is used in the production of fodder corn and clover and timothy hay. These soils are naturally well provided with lime and nitrogen, but in nearly all places they are so deficient in phosphate and potash that drainage alone does not insure satisfactory yields of farm or garden crops. It is necessary, therefore, to supply phosphate and potash, either in the form of stable manure or commercial fertilizers. Commercial fertilizers are preferable, as the manure can be used more profitably on mineral soils, because the nitrogen, its most valuable constituent for the mineral soils, is not needed on the peat soils which are naturally rich in available nitrogen.

The peat soils of Hennepin County are similar to those on the Coon Creek peat experimental field in Anoka County, which has been operated by the University of Minnesota since 1919, and the results of the experiments at Coon Creek, which have guided the reclamation of the Hennepin County bogs, are made use of in this discussion.

Some of the peat areas in Hennepin County adjoin or partly surround a lake, and the land surface is so little above that of the lake that satisfactory drainage is very difficult or even impractical. In some places proper drainage can be provided by pumping the water from the drainage system into a lake or stream, but this entails much additional expense. Most bogs, even after the installation of drainage sufficient for ordinary seasons, are liable to occasional flooding, following abnormally heavy rains, and potatoes and many other crops are drowned out when water stands at or above the surface of the soil for even a short time.

A serious handicap in the use of peat soils for sensitive crops, like potatoes and corn, lies in their liability to late and early frosts which may occur in any of the summer months and which vary greatly in frequency from bog to bog. Grasses and clovers are practically immune to injury from such frosts and are the safest crops on peat soils which are especially adapted for use as tame-hay meadows and pastures. In still another respect peat soils are at a disadvantage when compared with ordinary or mineral soils. When dry the peat may easily be set on fire accidentally, as from a dropped cigarette, the exhaust of a tractor, or a grass fire, and when once started peat fires are very difficult to extinguish. A single burning may so lower the surface of a drained bog as to make it too wet for cultivation and so make necessary further expense for drainage. More detailed information regarding the management of peat soils may be obtained from the division of soils, Minnesota Agricultural Experiment Station, St. Paul.

SOILS AND THEIR INTERPRETATION

Parts of two extensive geographic soil belts, both covering large areas in Minnesota, occur in Hennepin County. One is part of the dark-colored soil belt of western Minnesota, and the other is the southern extremity of the light-colored soil belt of northern Minnesota. The soils of the first belt are dark colored, because they have developed under a grassland vegetation and are known as the prairie or humid grassland soils, and the soils of the second belt are light colored, because they have developed under a forest vegetation in which the podzolization process has been very active.

Chernozem soils occur extensively and are well developed in the Red River Valley in western Minnesota and eastern North Dakota. To the west of it the zone of lime accumulation in the soil profile, which characterizes the chernozem soils, becomes better developed because of the aridity of the climate, but to the east, as the climate becomes more humid, the carbonate zone soon disappears. In Hennepin County the dark-colored soils have no well-marked carbonate zone but have the dark color and granular structure characteristic of the prairie soils. These well-drained dark-colored soils do not occupy a great part of the county, although they are confined to certain parts of it. Lines of demarcation separating them from the lighter-colored soils are not sharp and distinct and are therefore more or less arbitrarily drawn. In fact, a distinct transitional zone lies between the two main soil belts, in which the soils have features different from those typical of each belt. In addition to occupying this zone, the transitional soils also occur in large and small areas within both belts. To the east of the main transitional zone lie the light-colored soils, developed under a forest cover, which are widely distributed in northern and eastern Minnesota. These soils are very prominent in the county; in fact, the greater part of the soils of the county are light colored or podzolic, and many of the darker soils of the river terraces show evidences of podzolization.

Most of the soils of both belts have developed on unmodified glacial drift of late Wisconsin age, a strongly calcareous deposit which covers about two thirds of the State. Although most of this drift area is undulating, that in Hennepin County is largely morainic. An area in the vicinity of Medicine Lake and east of Lake Minnetonka consists of modified drift. The swift-moving waters issuing from the ice front at the time of deposition separated the finer material from the coarser and deposited it in stratified beds of coarse sand and gravel. Both Mississippi and Minnesota Rivers, formerly glacial streams of considerable size which carried a large volume of water during the closing stages of the glacier, laid down deposits of coarse sandy material in the beds of the former streams. Erosion by water since deposition, and in some places by wind, has resulted in an uneven surface relief, and in some places the relief is very pronounced. The valley soils in most places supported a fair or good growth of trees, although scattered patches of land were almost bare. On most of the soils, however, grasses grew rather luxuriantly, as is evidenced by the dark color of most of the surface soils.

As most of the parent material comprising the soils of the larger groups had good surface drainage from the time it was laid down, the soils developed on it have acquired certain prominent profile

characteristics, many of which bear a close relation to it. Where the various soil-forming processes have been allowed to proceed unhindered by poor drainage, excessive erosion, or other factors, the soil profile has developed certain horizon characteristics which have been determined by the character of the soil-forming processes and the composition of the parent material. The soil so developed is known as a mature soil, and each different parent material has developed a soil with distinct characteristics. All the soil types bear some close relation to the mature soils.

In the discussion of the soil types developed from the different parent materials, the mature soil of each group will be described first, followed by descriptions of its associated soil types. The river-valley soils, or the soils of the sand plain, will be considered first, followed by those of the rolling uplands of the unmodified glacial drift, and finally by those of the modified glacial material.

The soils of the Wadena series represent the mature soil of the river-valley group. Under normal development the topmost major soil layer, known as the A horizon, to a depth ranging from 10 to 14 inches, is dark-gray loamy sand or sandy loam, having a brownish cast in many places. Ordinarily it is structureless, but in some places where the soil is finer textured some granulation is in evidence. The A horizon passes more or less gradually into the second major soil layer, the B horizon, which is dark-brown or yellowish-brown sandy loam or heavy sandy loam. It is coherent and contains various quantites of fine material which gives it a somewhat plastic consistence when moist. When dry it becomes hard, the sand particles being more or less cemented together with the finer material. The average thickness of this horizon is about 12 inches, and in places brownish-yellow vertical blotches occur through it. The line of demarcation between the B horizon and the C horizon, or parent material, is not so sharply defined as that between the A and the B horizons. The B horizon merges gradually into the C horizon which consists of coarser yellowish-brown or grayish-yellow beds of coarse sand, fine sand, and gravel, although in some places it carries some finer material which gives it the texture of a light sandy clay loam. The deeper part of the C horizon, below a depth of 50 inches, becomes more stained with iron compounds, an evidence of the nearness of the water table. The lower part of this horizon is calcareous in most places.

The Wadena series is represented by two soil types, Wadena loamy sand and Wadena sandy loam. In surface relief, they range from level to gently undulating. Wadena sandy loam, which is the mature soil, has just been described. Where this soil lies close to the soils derived from heavier glacial drift, the subsoil contains much more fine material.

Wadena loamy sand is similar to Wadena sandy loam, except that the surface soil is sandier and the B horizon, both structurally and texturally, is not so well developed, being browner and containing more coarse material which does not have appreciable coherence. The C horizon also contains more sand and gravel, and it is very loose and incoherent. It is a more droughty soil than Wadena sandy loam.

Associated with the Wadena soils are the soils of the Hubbard series. Hubbard loamy sand and Hubbard sandy loam are mapped. Both are developed in the better-drained and drier situations. The

surface relief ranges from undulating to gently rolling, and the water table lies at a greater depth below the surface than in the Wadena soils. These soils have shallower surface soils than the Wadena soils, less prominent B horizons, and more uniform material comprising all horizons. Both the sandy loam and the loamy sand are developed on more or less well assorted sands, and very little gravel is present in the profile. The A horizon under virgin conditions is about 15 inches thick and consists of dark-brown structureless light sandy loam or loamy sand, composed of loose uniform fine sand or medium sand particles, but where the land has been cultivated the upper part of the A horizon is somewhat darker. The A horizon passes gradually into the B horizon which consists of yellowish-brown loamy fine sand with some finer material mixed intimately with it, giving it a somewhat loamy texture. The B horizon ranges from 10 to 12 inches in thickness and gradually merges into the C horizon which is loose incoherent yellow or yellowish-gray medium sand containing small quantities of fine and coarse gravel.

Hubbard loamy sand is similar to Hubbard sandy loam, except that the surface layer is coarser textured, the B horizon is less pronounced, and the C horizon is more variable in texture of the material, ranging from fine sand to coarse sand and fine gravel. Both of the Hubbard soils occupy areas having good drainage, and some areas occur on elongated ridges or elongated knolls of different sizes. A rather large proportion of the sandy loam type lies on gently undulating plains, and in some places it is closely associated with other sandy soils. In some places these soils have a much better developed B horizon than that described, and such areas have a higher agricultural value. They usually occur where the soil lies near or adjacent to the lowland soils. Some variation in the texture of the surface layers and in their lithological composition also occurs, and in some places the material throughout the profile consists of unassorted sands rather than the assorted material of the typical soils.

Closely associated with the Hubbard soils is Sparta loamy sand, the only member of the Sparta series recognized in the county. It is not an extensive soil. It is developed in areas having strong surface relief, where drainage is well established and the water table lies at considerable depth. This soil occupies prominent elevated positions, knolls, narrow ridges with rounded and smooth slopes, and plateaulike areas. Some of the land is subject to blowing, but tree growth in some places has prevented drifting. The surface soil is grayish-brown loamy fine sand which is variable in thickness but averages about 8 inches. This layer passes gradually into a 12-inch somewhat browner layer of loamy sand, without much coherence. The substratum is predominantly loose light-brown fine sand and is more or less free from the coarser sand particles.

The hydromorphic associates of the sand-plain soils are known as the Maumee soils, two types being recognized—Maumee sandy loam and Maumee loam. The profile of Maumee sandy loam consists of a surface layer, ranging from 10 to 16 inches in thickness, of dark-gray structureless fine sandy loam or sandy loam, which grades rather sharply into a dark brownish-gray layer of loamy coarse sand highly stained with bright yellow and orange, showing that its development has taken place under conditions of excessive moisture. The lower part of this layer becomes more uniformly gray or light gray,

the blotches being less numerous. The substratum material consists of light-gray medium sand or sandy loam, stained in places with vertical and horizontal yellow, orange, and brown spots and streaks. At various depths in the lower layers the glei [5] horizon is present.

The principal difference between the two Maumee soils is that Maumee loam has a finer-textured surface soil and a heavier-textured subsoil. In some places, the substratum material also is finer textured and the glei horizon occurs at different depths.

The Maumee soils in general occupy low-lying positions that are not continuously water-logged. They also occupy better-drained areas which encircle or surrround the large number of very poorly drained depressions. The soils in long narrow swales and level low-lying flats also are included in the Maumee series. On the better-drained areas and where artificial drainage has been established, some of these soils are under cultivation, but where the soils occupy small depressions that have not been artificially drained, most of them are not under cultivation. Most of the areas of these soils are used as wild-hay meadows or as permanent pastures.

Comprising the organic soils are extensive areas of peat and a very small area of muck. The peat deposits differ in thickness, some being less than 2 feet thick and some much thicker. Most of the muck is less than 2 feet thick. The peat consists largely of organic matter in various stages of decay, but the muck is everywhere dark colored and thoroughly decayed. Beneath the peat the mineral soil invariably consists of highly stained gray sand or sandy loam.

In plate 1 the various profiles of the soils of the sand plain show the characteristics of the mature soil and the associated soils.

The soils of the rolling uplands, unmodified drift, are developed on the limy drift of the late Wisconsin glaciation, most of which in Hennepin County was laid down as terminal moraines. Two very distinct and important soil groups are expressed on this till plain, the light-colored forest soils developed under forest cover and the dark-colored soils developed under a grass cover.

The mature soils of the group of light-colored soils are represented by members of the Hayden series and those of the dark-colored soils by members of the Clarion series. The Hayden series is represented by two soil types, Hayden loam, with a dark-colored phase, and Hayden sandy loam, and the Clarion series by one soil type, Clarion loam.

Hayden loam in its mature development is a typical podzolic soil, and its characteristics are similar in many respects to those occurring in large areas in eastern and northern Minnesota. It has developed on the very limy gray drift, under a mixed hardwood forest of maple, basswood, elm, oak, aspen, and birch. In its virgin condition the profile shows the following layers: The A_0 layer, which is a 2-inch matted layer of leaf mold and forest debris. The A_1 layer is gray structureless mellow fine loam or very fine sandy loam, 5 inches thick. This layer gradually passes into the A_2 layer, which is lighter-gray structureless mellow fine loam from 5 to 10 inches thick and practically devoid of dark-colored organic matter. The B horizon is well defined, sharp lines defining it from the A horizon above and the C horizon below. It consists of yellowish-brown compact sandy clay with

[5] The term "glei" is applied to that mottled part of the soil, below the normal C horizon, which is subject to ground water.

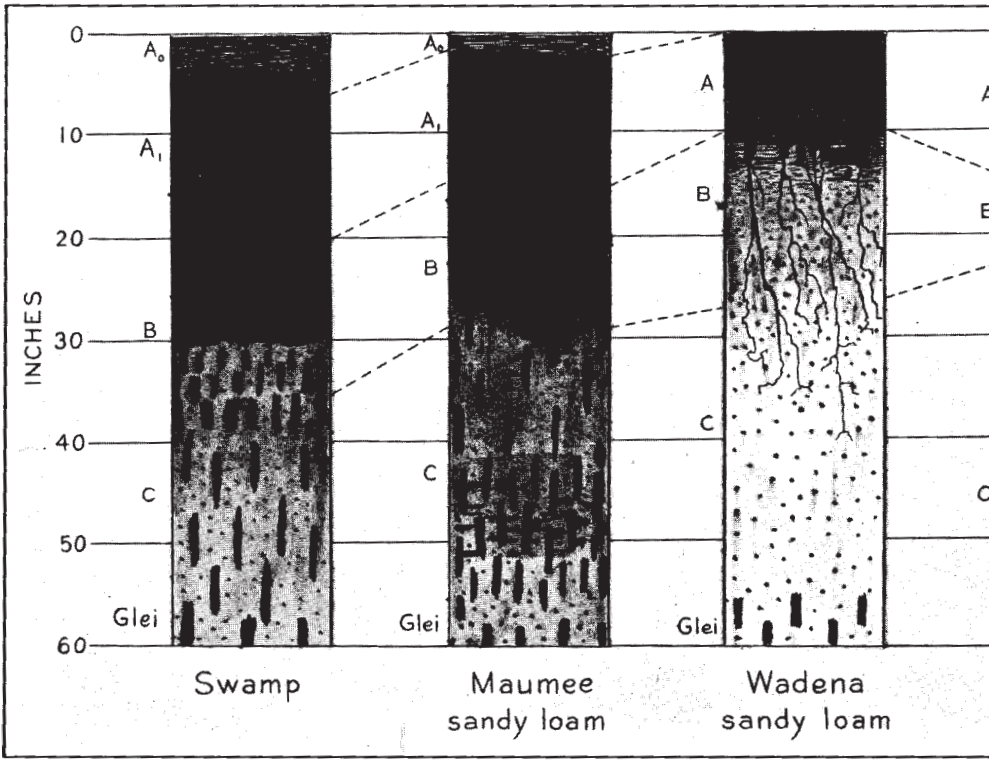

Diagram of soil profiles developed in sandy materials under varying degrees of drainage, progressing from a very wet c
drainage, as in Sparta loamy sand.

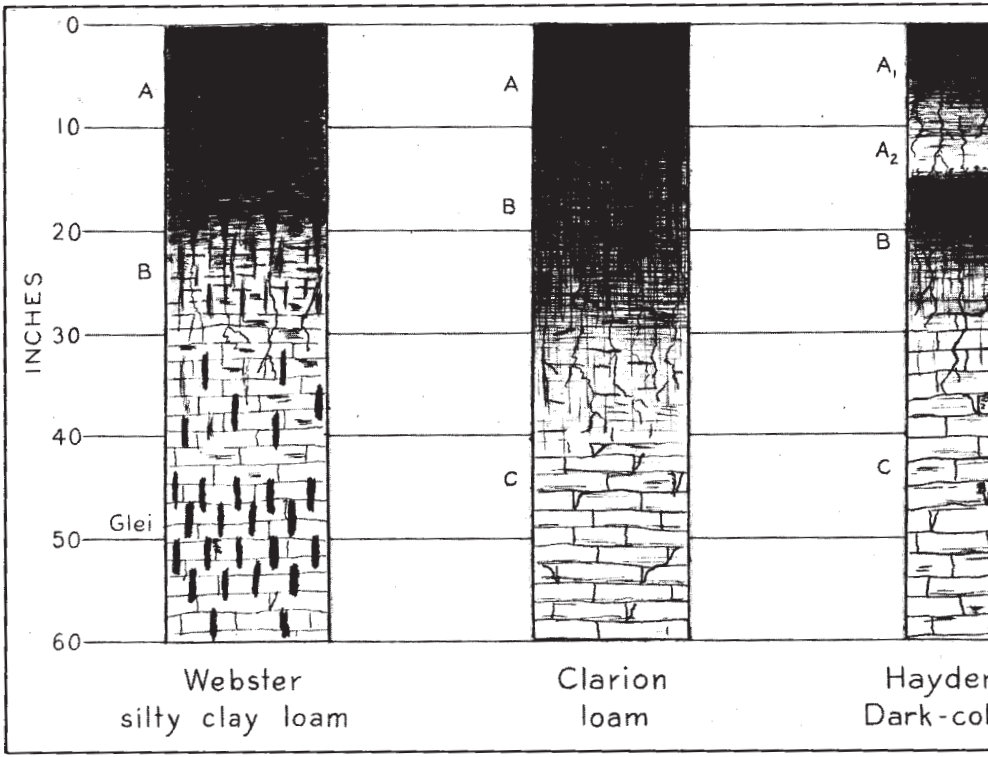

Diagram of soil profiles developed from heavy-textured materials under poor drainage, as in Webster silty clay loam; u
and under good drainage and timber cover, with varying degrees of podzolization, as in Hayden loam

pronounced cubical or blocky structure, marked by conspicuous horizontal cracks, in which many small rootlets appear. The upper part of the B horizon is grayer, owing to the infiltration of light-gray material from the A_2 layer into the breakage planes. The structural elements composing the B horizon are about the size of hazelnuts, and the outsides are coated with dark stainings of organic matter, but the interiors are almost free of such stains and are much lighter in color. When dry the material of this horizon is hard and very compact, but when moist it is easily penetrated by a soil auger or spade. The C horizon, the unaltered parent material, is amorphous yellowish-brown silty clay loam high in lime carbonate, some of which occurs as small pebbles but most of it intimately mixed with the soil material.

Variations from the typical soil commonly occur within short distances, the most prominent of which are dependent on the depth of the different horizons. The depth at which the soil effervesces with acid varies also, but ordinarily it is just below the B horizon though in many places it is some distance below this and well into the C horizon.

Associated with Hayden loam is Hayden sandy loam. This soil has developed in the more hilly and rougher areas and on parent material that has been subjected to partial modification during the time of deposition. The parent material includes a greater proportion of coarser particles than does that on which the loam has formed, and the horizons in the profile are not everywhere so sharply defined. Greater variations in all characteristics of the profile are likewise noticeable. As with Hayden loam the A_0, A_1, and A_2 layers of the sandy loam show some variations in depth and texture, but the surface soil in most places is coarser textured. The B horizon in most places is sufficiently developed to exhibit typical podzolic characteristics, but they are not so well expressed, and the sandy loam is not so compact and does not contain so much fine material as the loam. The C horizon is much more variable in composition than either of the other two horizons. In some places sand and gravel predominate over the fine material, but in other places there is more fine material than sand. Considerable variations exist in the depth of the A and B horizons. Most of the Hayden sandy loam lies in the regions of strong relief, in places where erosion is more or less active. Inasmuch as the soil is so closely related to Hayden loam and both soils occupy situations of strong relief, considerable overlapping of areas of the two soils occurs in mapping. In many places small patches of this soil, too small to be shown on the map, are included with Hayden loam.

Clarion loam in its typical development is a true prairie soil. It has a dark surface soil, good granular structure, and lacks the gray layer (the A_2 layer) of the podzolic soils. Like the Hayden soils it is developed on the limy late Wisconsin drift and in most situations has developed into a mature soil. This soil generally occupies the smoother areas, although it is well developed in some places where the relief is very strong.

The profile of Clarion loam shows the following horizons: An A horizon which is very dark gray or black fine-granular silt loam or loam, from 8 to 12 inches thick, filled with a mass of fine grass roots. This gradually changes to the B horizon, consisting of dark grayish-brown silty clay loam which becomes browner as the depth increases. This horizon extends to an average depth of 20 inches and, like the

surface soil, is finely granular, with numerous grass roots filling the soil. Horizon B gradually gives way to the C horizon, the line of demarcation between the two being less pronounced than that between the A and B horizons. The material of the C horizon is grayish-yellow silty clay loam containing considerable calcareous material intimately mixed with it.

Clarion loam, like the other drift soils, shows variations in its composition. As so much of this soil closely resembles the cultivated Hayden soils, it is difficult to everywhere accurately separate the soils of the two series. Much of the soil which lies in the transitory belt does not have all the characteristics of the Clarion soil, on the one hand, or of the Hayden soils, on the other, but has some characteristics of both.

The first difference to be observed in passing from the light-colored to the dark-colored soils is the gradual change to a darker surface soil and the lessening of the thickness of the podzolized gray layer. The B horizon also gradually loses the typical podzolic structure and becomes more granular, which is typical of prairie soils. Because of these pronounced but intermediate features, it seemed desirable to separate such soil, but, rather than recognize a distinct soil type to identify it, it has been included in the Hayden series because of its podzolic characteristics. It is designated as a dark-colored phase of Hayden loam. The surface soil is dark gray, similar to that of Clarion loam. However, it is not so thick as the surface soil of Clarion loam, and it is more or less granular. Just below the lower part of the dark layer, the soil is grayer and similar in characteristics to the A_2 layer of the typical Hayden soils. The B horizon also lacks the characteristic granular structure of Clarion loam but is more typical of that of Hayden loam, consisting of angular blocky structural aggregates. The C horizon is similar in all respects to the C horizons of the other soils of this group.

The soils of the rolling upland, modified drift, constitute a comparatively small part of the morainic deposits of Hennepin County, which have been subjected to modification during deposition of the soil material—modified to the extent that the material comprising the drift underwent some assorting by the immense volume of water flowing from the melting ice. This removed and carried away much of the finer material incorporated with it, leaving behind the coarser fragments of sand, gravel, pebbles, and stones, some of which were arranged in stratified layers. Much of the modified material lies in areas where the surface relief is as pronounced as that where no modification took place. A layer of finer material has been deposited on some of this coarser material in some unknown manner, possibly by a readvance of the ice. This layer of finer material is variable in thickness, ranging from less than 10 inches to more than 3 feet.

On these modified morainic deposits the Thurston soils have developed. Two soil types and one phase are mapped, Thurston loamy sand, Thurston sandy loam, and Thurston sandy loam, shallow phase.

Thurston sandy loam has an A horizon which consists of an 8-inch layer of structureless dark-gray or brownish-gray sandy loam. It passes rather abruptly into the B horizon of dark yellowish-brown or reddish-brown gravelly loamy sand containing many pebbles and small cobbles. The B horizon is more or less devoid of any definite structure, but it contains some fine material which gives it a certain

amount of coherence. When dry the material is somewhat hard. Beneath the B horizon, which ranges from 12 to 16 inches in thickness, is the C horizon consisting of calcareous gravelly sand or sandy loam considerably stained with iron compounds carried down from the upper horizons.

The shallow phase of Thurston sandy loam is similar to the typical soil, except that the A and B horizons are thinner. Where the combined thickness of the A and B horizons does not exceed 24 inches, the soil has been mapped as a shallow phase.

Thurston loamy sand differs from the other members of the Thurston series in that the surface soil is coarser textured and the B and C horizons consist of fine or medium sand instead of coarse sand and gravel.

All the Thurston soils show much variation in the thickness of their horizons and in the texture of the substratum. They are developed on loose sand or gravel, and in some places sand is more abundant than gravel. In many places the substratum consists of very coarse gravel. In some places, where the coating of fine material is 3 feet or more thick, the soil has a much higher agricultural value than the shallower areas which are very droughty and on which crops suffer severely from lack of moisture during dry spells.

The hydromorphic associate of the upland drift soils is termed Webster silty clay loam. In the aggregate it occupies a large area, though no one area is very extensive. This soil is developed in low swales, depressions, and along many of the streams and drainage ways. All of it is poorly drained, and its development has been influenced by the presence of water for long periods. The surface soil is very dark gray or almost black and in some places is mucky. Ordinarily the texture is fine loam or silt loam, but it may range from sandy loam to clay loam. In many places it consists of material washed in from the surrounding slopes, and in many places the dark soil extends to a depth of more than 30 inches. The dark color of the surface soil gradually changes to gray and, in turn, to still lighter gray material which in many places is mottled and streaked with bright-colored iron stains. At variable depths below the surface the glei layer is present. In all places the deeper part of the subsoil consists of fine-textured calcareous material, clay loam and even fine clay in some places. Practically none of the land is under cultivation, and very little has been artificially drained.

In plate 2 are shown the various profiles of soils of the glacial drift.

SUMMARY

Hennepin County lies in the eastern part of Minnesota, north of the junction of Minnesota River with the Mississippi. The land area of the county is 565 square miles, or 361,600 acres.

The surface relief ranges from gently undulating to sharply rolling. The smoother areas occur on the outwash sandy plains along parts of Mississippi and Minnesota Rivers, and the rougher parts lie beyond these on the glacial deposits. The morainic region is dotted with many clear-water lakes, the largest of which is Lake Minnetonka. The whole county drains into Mississippi River either directly or through its tributaries. The average elevation above sea level is about 925 feet.

Hennepin County was organized in 1852. Settlement of the rural districts began in 1823. The population, according to the census of 1930, is 517,785, of which 33,976 are classed as rural. Other than native-born Americans, the population of the county is made up largely of Swedes, Norwegians, and Germans, and other nationalities are represented in smaller numbers. Minneapolis, the county seat, with a population of 464,356, is the largest city in Minnesota. It is an industrial center, a distributing point, and a railroad center. The county is well supplied with local markets and railroad facilities, and good roads extend to all parts.

Climatic conditions are favorable for agriculture. The mean annual temperature as reported at Minneapolis is 44.5° F., and the mean annual precipitation is 27.66 inches. The normal growing season, or the period free from killing frosts, varies rather widely in different parts of the county, from 137 days at Maple Plain in the west-central part to 164 days in the heart of Minneapolis. The mean annual precipitation at Maple Plain is nearly 3 inches more than at Minneapolis.

The agriculture consists mainly of general farming combined with dairying. The common cereal crops are corn, oats, wheat, barley, and rye. Alfalfa, clover, and timothy are the principal hay crops. Special crops, such as potatoes and truck crops are grown extensively in different parts of the county. The trucking industry is extensively developed in the vicinity of Minneapolis. In 1929 the value of dairy products amounted to $3,274,560, and the total value of poultry and eggs was $1,044,558.

The soils of the county are derived from glacial till, water-laid materials, and peat. Thirteen soil types and two phases of types are mapped, in addition to peat, with a shallow phase, and muck, and miscellaneous classifications of alluvial soils, undifferentiated, beach sand, made land, steep broken land, and unclassified city land.

There are three distinct groups of soils in the county, the most extensive being the upland light-colored well-drained soils which are derived from the limy gray drift of the late Wisconsin glaciation. Originally these soils were covered with a thick stand of mixed hardwoods, but most of the timber has been removed and the land is now in farms. Next in extent are the dark-colored fine-textured prairie soils which occur largely in the western part. These soils are derived from the same material as the soils of the first group, but instead of being forested they were originally in prairie. Their dark surface color is owing to the accumulation of vegetable matter supplied by the roots of wild grasses. The third group consists of the sandy soils along Mississippi, Minnesota, and Crow Rivers. Most of the areas of these soils are devoted to mixed farming and truck-crop growing. They are variable in composition and differ in productiveness.

Hennepin County includes a very large total area of peat and other naturally poorly drained land, some of which has been reclaimed. Much of the wet land lies in the region of the heavier soils, in depressions and bordering some of the small streams and drainage ways.

○

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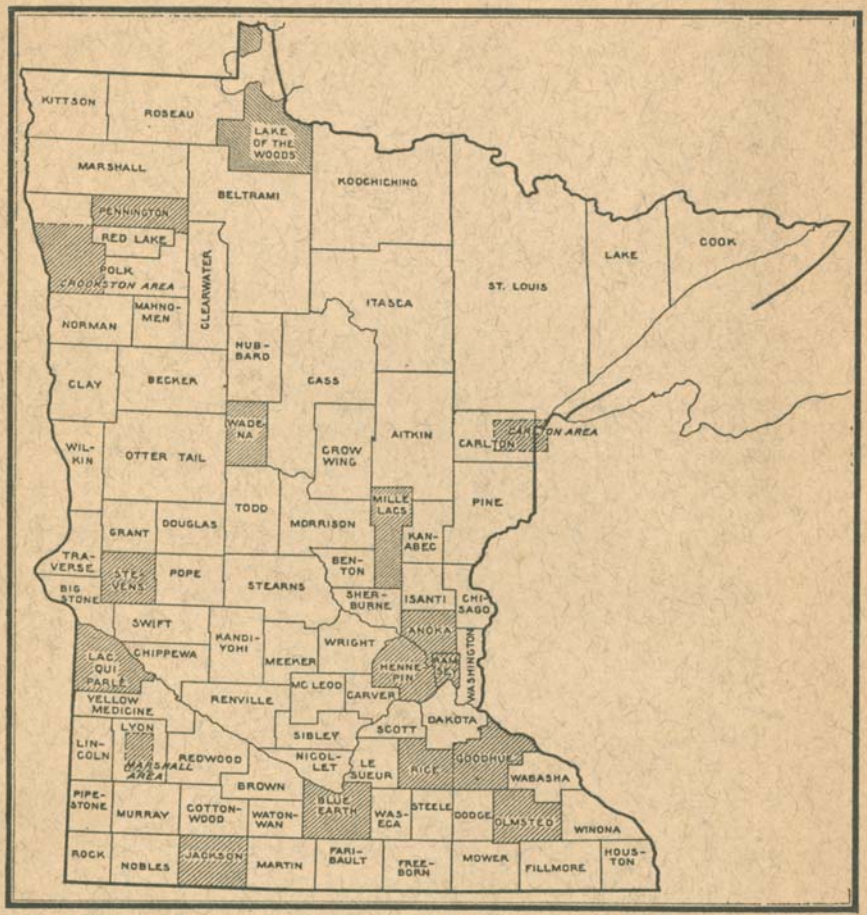
There shall be printed, as soon as the manuscript can be prepared with the necessary maps and illustrations to accompany it, a report on each soil area surveyed by the Bureau of Chemistry and Soils, Department of Agriculture, in the form of advance sheets bound in paper covers, of which not more than 250 copies shall be for the use of each Senator from the State and not more than 1,000 copies for the use of each Representative for the congressional district or districts in which a survey is made, the actual number to be determined on inquiry by the Secretary of Agriculture made to the aforesaid Senators and Representatives, and as many copies for the use of the Department of Agriculture as in the judgment of the Secretary of Agriculture are deemed necessary.



Areas surveyed in Minnesota, shown by shading. Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southeast hatching.

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BUREAU OF CHEMISTRY AND SOILS
HENRY G. KNIGHT, CHIEF
A. G. McCALL, CHIEF, SOIL INVESTIGATIONS
CURTIS F. MARBUT, IN CHARGE SOIL SURVEY

SOIL MAP
HENNEPIN COUNTY
MINNESOTA

UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION
W. C. COFFEY, DIRECTOR
F. J. ALWAY, IN CHARGE SOIL SURVEY

R.24W. R.23W. R.22W. R.21W.
93°45' 40' 35' 30' 25' 20' 93°15'
T.120N. T.119N. T.118N. T.117N. T.116N.
45°10' 05' 45°00' 55' 44°50'
T.120N. T.119N. T.118N. T.29N. T.28N. T.27N.

LEGEND

Clarion loam — Cm	Sparta loamy sand — Sl
Hayden sandy loam — Hy	Thurston loamy sand — Td
Hayden loam — Ha	Thurston sandy loam — Ts
Ha — Dark-colored phase	Ts — Shallow phase
Hubbard loamy sand — Hd	Wadena loamy sand — Wd
Hubbard sandy loam — Hm	Wadena sandy loam — Wy
Maumee sandy loam — My	Webster silty clay loam — Wc
Maumee loam — Mm	Muck — Mu
Alluvial soils (Undifferentiated) — A	Peat — P
Beach sand — Bd	P — Shallow phase
Made land — Md	Unclassified city land — Uc
Steep broken land — St	Depressions

CONVENTIONAL SIGNS

CULTURE (Printed in black)
- City or Village, Roads, Buildings, Wharves, Jetties, Breakwater, Levee, Lighthouse, Fort
- Secondary roads and Trails
- Railroads, Steam and Electric
- Bridges, Ferry
- R.R. crossings, Tunnel
- Ford, Dam
- School or Church, Cemeteries
- Mine or Quarry, Mine dumps, Made land
- Bluff, Escarpment, Rock outcrop, and Triangulation station
- Sharp and Gravelly areas
- Soil boundaries
- Boundary lines
- Boundary lines
- Boundary lines
- U.S. township and section lines

DRAINAGE (Printed in blue)
- Streams
- Lakes, Ponds, Intermittent lakes
- Intermittent streams
- Springs, Canals and Ditches, Flumes
- Swamp, Salt marshes
- Submerged marsh, Tidal flats

The above signs are in current use in the soil maps. Variations from this usage appear in some maps of earlier dates.

RELIEF (Printed in brown or black)
- Contours, Depression contours
- Pyramidal Hills, Mountain Peaks
- Sand Wash and Sand dunes
- Shore and Low water line, Sandbar

Mark Baldwin, Inspector, District 1.
Soils surveyed by P. R. McMiller, in charge, C. C. Nikiforoff, E. A. Fieger, Sam Hill, and C. H. Mattson, University of Minnesota, and G. A. Swenson and W. C. Boatright, U. S. Department of Agriculture.

BASE MAP IN PART FROM U. S. GEOLOGICAL SURVEY SHEETS

Scale 1/126720
1 0 1 2 3 4 Miles
1 0 1 2 3 4 5 Kilometers

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Field Operations
Bureau of Chemistry and Soils
1929